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INSTRUMENT
INSTRUCTIONS

ESD

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, N.Y.

Symbol of Quality

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Instrument No.

INSTRUCTION MANUAL

FOR

OPERATING AND MAINTENANCE

OF

ELECTROSTATIC VOLTMETERS

MODEL ESD

TYPE Double Pivoted Moving Vane

ACCURACY 1%

SCALE LENGTH 5.2"

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ELECTRICAL MEASURING INSTRUMENTS

ELECTROSTATIC VOLTMETERS

As electrostatic effects are due entirely to voltage, the first consideration in understanding electrostatic voltmeters is the fundamental one that;

"THEY ARE VOLTAGE OPERATED!"

Electrostatic Voltmeters are a logical instrument development from the very earliest gold leaf electrometers. (John Canton 1718 A.D.) Electrostatic Voltmeters as they are made today utilize either the repulsion or attraction principle of electric charges.

The two elementary properties of an electric charge are that LIKE POLES REPEL and that UNLIKE POLES ATTRACT.

The repulsion type of electrostatic voltmeter makes use of the LIKE POLES REPEL effect and the attracted design of electrostatic Voltmeter makes use of the UNLIKE POLES ATTRACT effect to create a torque between metal surfaces that can be used for purposes of voltage measurement.

COULOMB'S LAW states that the force of attraction between unlike charges is proportional to the product of their magnitude or the torque on a suitable pivoted moving vane system is proportional to the SQUARE of the applied voltage.

If the instantaneous terminal voltage is steady D.C., then the average torque which produces the deflection is the same as the instantaneous torque, and the instrument reads D.C. voltage. On A.C. this results in the alternating voltage producing surges or torque which are mechanically averaged by the instrument movement. The instrument movement can do accurate averaging because it has a mechanical time constant which is very long compared to the period of the alternating voltage being measured. Consequently, the instrument responds to the theorectical concept of root mean-square voltage, regardless of wave shape.

The deflection is directly proportional to the RMS value of the voltage appearing between the plates of the moving elements. On D.C. the instrument draws a MOMENTARY charging current which almost instantly drops to a very negligible value which is determined by the insulation resistance of the instrument. The insulation resistance will vary only slightly with environmental conditions. However, under worse conditions the current drawn by the instrument from this cause is several hundred times smaller than the current of any other type of voltmeter. The charging current is almost always a negligible quantity. Its exact value, of course, is determined mainly by the inductance and resistance of the external circuit. In most cases the electrostatic voltmeter can be safely considered a zero current device.

On A.C. there is a very small current consumption because the electrostatic voltmeter is essentially a variable condenser, but there is NO POWER CONSUMPTION as any current flowing is actually wattless. Any current on A.C. that flows will be proportional to the frequency of the A.C. so that electrostatic instruments must be used with care on radio frequency circuits.

MULTIRANGE INSTRUMENTS FOR DIRECT CURRENT

Electrostatic Voltmeters cannot readily have their ranges extended to measure higher D.C. Voltages unless the mechanical dimensions (spacing) of the electrodes can be easily changed by mechanical means.

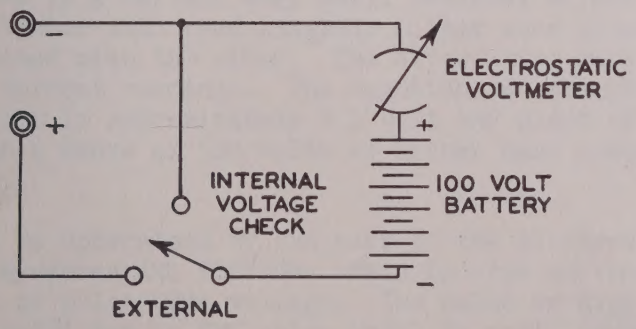
Since sensitivity of an electrostatic voltmeter depends upon the spacing of the electrodes, we can vary the sensitivity by varying the electrode spacing. The SENSITIVE RESEARCH Model ESH high voltage electrostatic voltmeter uses this principle in a very refined mechanism for positioning the stationary electrode in as many as four positions to obtain up to four ranges of voltage measurement with one instrument. It also has the advantage of the capacity of the voltmeter becoming LOWER as the voltage ranges are increased.

SENSITIVE RESEARCH accomplishes this mechanically in our Model ESH multi-range instrument having a low range of 5000 volts full scale (1000 Volts lowest possible reading.) However an electrostatic voltmeter of higher range can within reason be used to measure lower voltages by the use of a battery in series with it. The circuit shown below will take NO CURRENT from the battery but its voltage will be added to a small external circuit voltage and the total voltage read on the best portion of the voltmeters scale.

EXAMPLE:

Assuming a voltmeter of 120 volts full scale with its best portion of its scale about 100 to 120 volts. Then using the circuit shown below and a 100 volt battery. Then external circuit potentials of 1 volt are quite easily read, the electrostatic voltmeter reading for instance 101 volt;

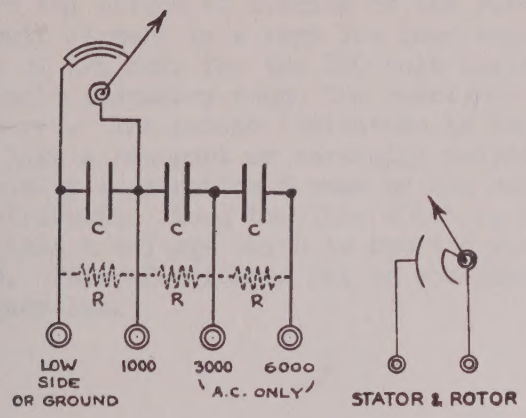
101 Volts
- 100 Internal battery Volts
1 Volt External Value



In any case when using the above method for very low D.C. Voltage measurement DO NOT exceed a battery voltage of more than 50% above the normal rating of the electrostatic voltmeter.

A.C. MULTIRANGES

Multiranges on A.C. offer NO PROBLEM because a condenser multiplier can be used (our mould ESD) or as well as mechanical means (our Model ESH)



MULTIRANGE

The low voltage model ESD electrostatic voltmeters obtain their multiranges by different means. It is not convenient to vary the spacing of the electrodes in the more sensitive instruments and so capacity type voltage multipliers are used. From the circuit shown above it will be seen that the condensers "C" will form a voltage divider for A.C. components which will provide accurately fixed multiplying factors. The resistances shown as "R" in dotted lines are the upsetting factor when D.C. is applied. These represent the leakage resistances and the voltage appearing across the movement is proportional to these uncertain leakages and hence of a very variable value.

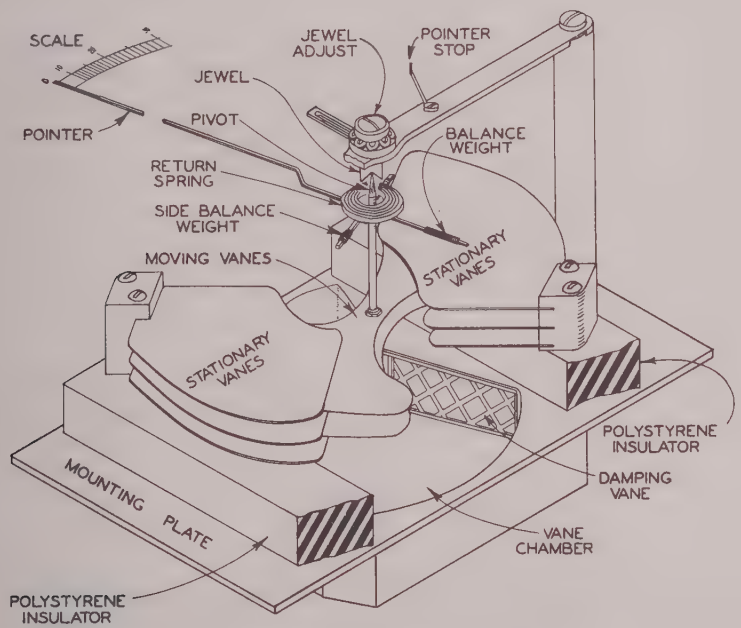
Because of the uncertainty of these leakages, multirange type ESD instruments should be used for D.C. readings ONLY ON THE LOWEST RANGE.

Due to contact potentials which unavoidably exist between the dissimilar metals which are used in the construction of high sensitivity electrostatic voltmeters, there is a certain very small reversal effect on direct current. A low range voltmeter will read slightly higher when connected in one polarity then when connected with the other. The alternating current will read between the two direct current readings. The magnitude of the potential is such that the reversal error is approximately ± 1 volt any place on the instrument scale. Instruments with a range of 500 volts or higher have a negligible A.C. and D.C. difference.

It should be understood by the user of the electrostatic voltmeter that the instrument measures RMS VOLTAGE. This is true whether the voltage is D.C. sinusoidal A.C. or pulse type voltage. The pulse or high peaked type of voltage wave usually has an RMS value which is small compared to the peak value. This sometimes misleads the user into thinking that the instrument is not functioning properly. Sometimes, as in a typical radar measurement, the ratio of peak to RMS may be as much as one thousand to one. In applications such as radar pulse measurement, ignition voltage measurement, or any peaked or pulse measurement, we recommend the use of a SENSITIVE RESEARCH Peak Voltage Unit with our Electrostatic Voltmeters.

The frequency range of an electrostatic voltmeter is quite broad. There are two phenomena which place the UPPER LIMIT on the use of the electrostatic voltmeter. The first is the effect of loading on the circuit being measured. The voltmeter as a circuit element is a very low loss capacitor. Its capacitance lies between the limits of 225 mmf. for the 120 volt instruments to about 10 mmf. for the 60 kv. In the radio frequency range the reactance of the instrument is a quantity to be considered. The second limitation is that of the instrument and its leads behaving like a resonant or partially resonant transmission line. The leads and the capacitive termanation formed by the voltmeter movement may result in a voltage distribution along the line which is not constant. Thus the instrument may indicate a voltage which is not the same as that to which the leads are connected. This effect need not be considered at frequencies lower than about 10 megacycles.

MECHANICAL DESIGN



ELECTROSTATIC MOVEMENT

Our portable cased Model ESD electrostatic Voltmeter uses the above instrument design. The two (2) highly insulated stationary vanes are connected to the "HIGH SIDE" of the circuit which is indicated by engraved insulated binding posts. The duraluminum moving vane (or vanes) is usually connected to the ground or "LOW SIDE" of the circuit being measured. (See marked binding posts. The stationary and moving vanes are shaped so as to obtain the desired scale proportionality. The moving vane shaft is pivoted at both ends, one end of which is attached the usual spiral restoring spring. Damping is accomplished by a vane moving in an almost air tight chamber. Shock mounted jewels and "diamond pivots" are used in the most sensitive (low voltage) designs.

The instrument glass is conductive on its underside which prevents it from acquiring electrostatic charges.

OPERATIONAL PROCEDURE

A. Place the instrument on an approximately level surface. For best accuracy do not use at an angle of more than 5 ° from the horizontal in any direction.

B. Set the pointer on zero by rotating by hand the zero shifter on the top of case. The pointer is correctly set on zero when the pointer and the zero line of the scale coincide.

C. Turn off voltage to be measured before making any high voltage connections to the instrument.

D. Connect the voltmeter to the circuit to be measured, making sure that the low side, or ground, binding post (See figure #1) is connected to the side of the voltage circuit that will be at ground or nearest ground. Connect the high side binding post to the high potential side of the voltage potential circuit to be measured.

E. On the Model ESH Multirange instrument, set the voltage range selector slide rod (figure #2) to the position (See instruction plate on rear of instrument case) required for the voltage to be measured. If in doubt as to value of voltage, start measurements with slide all the way out, which is the highest range. Apply voltage and wait for the pointer to come to rest. If the high range does not produce an easily read deflection, turn voltage off then push slide in to the next "click" position. Repeat the above applying voltage again. Be sure that the "Click Position" is positively restraining the slide in a definite position.

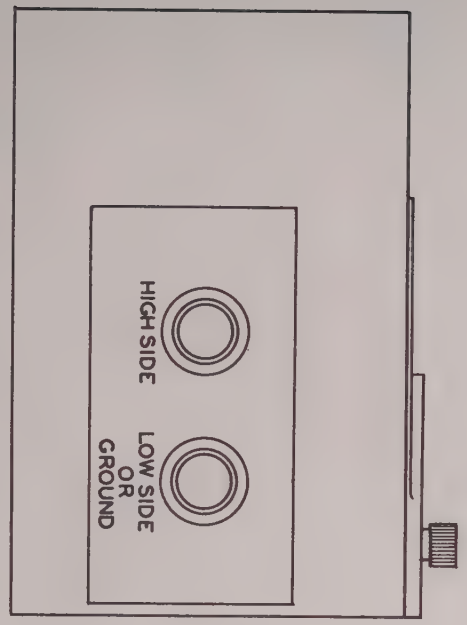
F. Read the voltage. Please note that there is a separate hand drawn scale for each range in volts. Be sure that you are reading the correct scale.

CAUTION

DO NOT TOUCH THE HIGH VOLTAGE BINDING POST OF THE ELECTROSTATIC VOLTMETER WITHOUT FIRST REDUCING THE VOLTAGE TO ZERO. KEEP HIGH VOLTAGE SLIDE CLEAN AND FREE FROM MOISTURE. IN CASES OF HIGH ROOM HUMIDITY, TURN OFF VOLTAGE, AND WIPE THE REAR ELECTRODE INSULATION WITH MOISTURE ABSORBENT PAPER OR CLOTH.

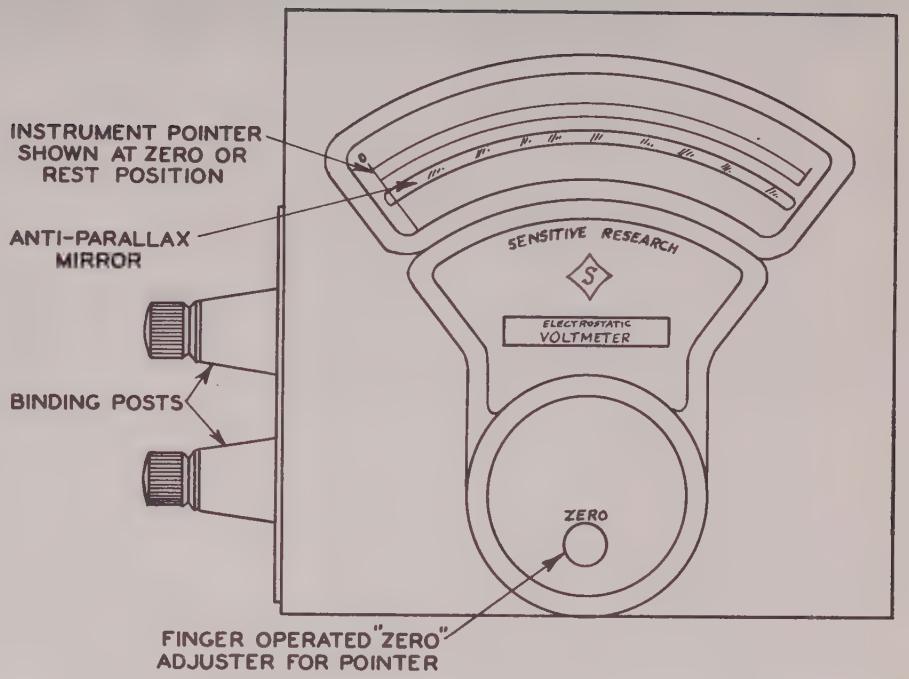
SENSITIVE RESEARCH Electrostatic Voltmeters are completely hand built and hand calibrated. Extreme care has been used in selecting non-ferrous pivots and natural sapphire, shock-mounted jewel bearings.

The instrument should be used and treated as a precision instrument standard. A small amount of care will bring its return in a lifetime of satisfactory instrument operation.



LEFT SIDE OF INSTRUMENT CASE

FIGURE 1



TOP VIEW OF INSTRUMENT PANEL

FIGURE 2

MODEL ESD

HAVING RANGES UP TO 6000 VOLTS

GENERAL INFORMATION

Upon receipt, your instrument should be carefully unpacked and examined for any visible external damage, i.e; split case, cracked glass, broken binding posts, etc. Place the instrument on a reasonably level bench. If the instrument has a wire shunting (across) the terminals, it should be removed. With the mechanical zero adjuster thumb knob, move the pointer both above and below the zero line of the scale. It should have sufficient travel to go a little beyond zero in each direction. Set the pointer exactly on zero while lightly tapping the instrument case with your fingers. The pointer will be correctly adjusted for zero when no reflection of the pointer's knife edge can be seen in the anti-parrallax mirror and the pointer is directly over and in line with the scale zero.

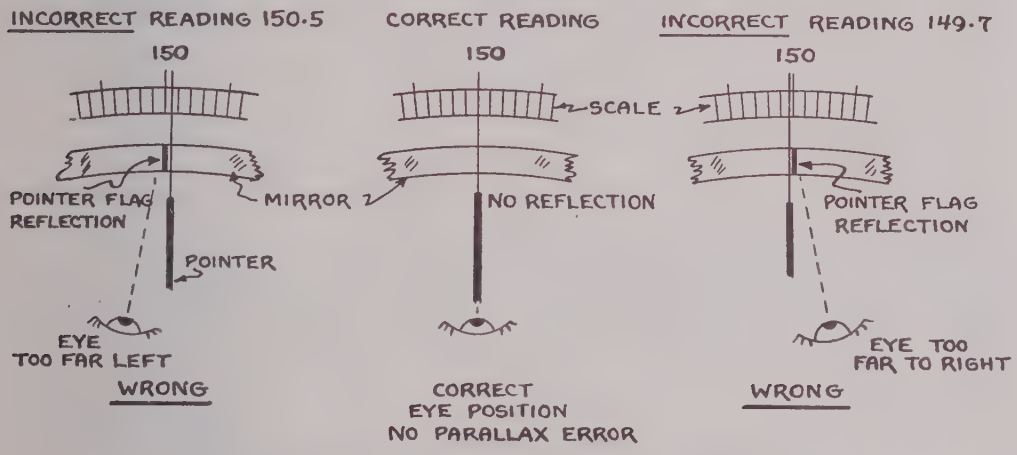


ILLUSTRATION OF THE ANTI-PARALLAX PRINCIPLE

The pointer indication should only be "read" when no reflection of its knife edge can be seen in the mirror below. This is only obtained when the eye is directly over the pointer. The drawings above illustrate the anti-parallax principle.

BALANCE TESTS FOR DIRECT CURRENT INSTRUMENTS

The general testing procedure for balance on all portable and panel instruments is the same, the difference being only in the degree of angle that the instrument is tipped from a horizontal position.

1. See that the pointer is set exactly on its zero position.

2. Now tip the instrument slowly up from the side farthest from you to an angular position as shown on the table below, and tap gently. The pointer should NOT move more than the amount shown on the table below.

3. Next, lay the instrument flat again and then tip it on its side, both left and right, and tap gently.

In both of these procedures, the instrument should be within its balance specifications. In general, these specifications are as follows:

ALTERNATING CURRENT INSTRUMENTS

MODEL	ACCURACY	ANGLE FROM HORIZONTAL	BALANCE GUARANTEE
A (ALL THERMALS)	.75 of 1%	15°	.75 of 1%
MI,D,DW, UNIVERSITY	.5 of 1%	25°	.5 of 1%
D, DLW	.25 of 1%	25°	.25 of 1%
L (LAB. ST'DS	.1 of 1%	10°	.1 of 1%

FRICTION TESTS

The instrument may be tested for mechanical friction at this point, by connecting it to a suitable source of power and deflecting it at least 25% of full scale, then reducing the deflecting current to zero. No instrument should be accepted for use if it has any appreciable friction.

CALIBRATION CHECK

No actual calibration check should be made until the instrument has become thoroughly temperature saturated at ambient room temperatures for at least four hours. (Allowed to reach room temperature.) SENSITIVE RESEARCH calibrates all instruments at exactly 25° C.

Make sure you are on the right range for your power supply. If in doubt set the range switch if any, on the instrument, on its highest range. This will prevent overloading of the instrument when starting any electrical tests. If only a slight pointer deflection results when power is applied, then successively switch the instrument range selector DOWN until a suitable reading is obtained. Bring the pointer up to full scale and open the instrument circuit. A special precaution should be taken by the user of thermocouple instruments, and that is to AVOID opening the primary circuit of a transformer whose secondary circuit is being measured by thermocouple instruments. The reason for this is that the transformer as an energy storing device, may, under certain conditions, DISCHARGE its energy into the secondary circuit, thereby overloading the thermocouple instrument. (Overloads of 1000% are quite possible in transformer circuits.)

This danger can be eliminated by either disconnecting the instrument from the secondary circuit which can be turned to "zero" so that the excitation of any transformer primary may be reduced to "zero" before switching off.

The pointer should return to its original zero without tapping. If it returns to zero only when tapped, it indicates friction in the movement and possible damage to the pivots and jewels, possible through some severe shock in transit. For portable instruments with an overall accuracy of .5 of 1% or higher, and all high torque panel types, the pointer should return to exactly zero. Ultra high sensitivity instruments in the 1% class, and thermocouple instruments in the .75 of 1% class should have a maximum deviation from zero to no more than .1 of 1% of the physical length of the scale.

The pointer should then be deflected using controlled power slowly up and down the instrument scale. The pointer action should be smooth and there should be no sticking or hesitation at any point on the scale. Do not, however, mistake a rough spot in the controls of your power supply for a "stick" in the movement. Often, a badly regulated power supply or a loose circuit connection may make the instrument appear to have an internal variable. All instrument links and leads should be carefully attached and tightened.

The new instrument should be checked against an accurate standard on the cardinal points of the scale. Just one word of CAUTION. Be careful that you do not place your new instrument and your standard too close together, especially with D.C. instruments. They may react magnetically on each other if your standard instrument is not magnetically shielded, it might indicate incorrect readings. Keep them at least six inches apart. Also, if the instrument was specially ordered for use on a steel panel (such information is printed on all our scales) then test it on a steel panel of the specified thickness.

Of all the things, that may be wrong when you get a new instrument, incorrect calibration is the LEAST likely; and if present at all, it will usually be caused by bad balance which you will already have detected by the test just covered. 99.99% of the instruments you receive, if they are satisfactory for balance, friction, stickiness etc., will also be well within their guaranteed accuracy.

NOTE:

Disassembly of the movement should not be attempted unless a skilled instrument man with calibration and scale drawing equipment are available.

CARE AND MAINTENANCE

All SENSITIVE RESEARCH instruments are individually assembled by skilled instrument makers and are INDIVIDUALLY calibrated. We do not calibrate instruments "en masse". Extreme care has been used in selecting pivots and shock mounted jewel bearings. In some instruments DIAMOND PIVOTS are used.

The instrument should be used and treated as a precision standard. A reasonable amount of care will bring its reward in a lifetime of accurate service.

Good practice dictates that periodic checks be made for pivot friction, coil, balance, scale calibration, and the mechanical integrity of any instrument.

If the instrument glass is cleaned by any method, the task should be completed by heavily breathing upon the glass so as to dissipate any electrostatic charges that may have been generated by friction. Occasionally the binding posts metal contact surfaces should be cleaned and brightened by the careful use of a fine sandpaper. A yearly coat of wax on any wooden instrument case is suggested.

Instrument panels are cleaned by using carbon tetrochloride to dissolve any greasy surface accumulations. A brisk rubbing with a soft flannel cloth will restore our moulded panels to their original lustre. Should the engraving "white" become discolored it can be removed with a sharp point and refilled with a white wax crayon material obtained from us.

OPERATIONAL PROCEDURE

1. Place the instrument on a level surface so that the scale is horizontal. Deviations of more than 5^{o} from the horizontal may affect accuracy adversely.

2. For good instrument practice, the instrument should be kept away from any source of very strong magnetic fields. Maximum tolerable field is 5 oersted.

3. Set the pointer on zero by rotating the zero shifter, using thumb or zero screw. The pointer is correctly set on zero when the reflection of the pointer in the antiparallax mirror coincides with the pointer itself and with the zero line. (See general information sheets.) Page 4

4. For safety it is best to turn off the current or voltage to be measured before making connections to any instrument. Observing proper polarity, connect the instrument terminals in series with the circuit if current is to be measured.

   If voltage is to be measured then the voltmeter is to be in parallel to the portion of the circuit desired. It is important to remember that when an ammeter (current measuring instrument) is inserted in series with a circuit, the circuit is changed by the introduction of the ammeter resistance. Ammeters are therefore designed to be of low resistance so that they will only be a small fraction of the total resistance of a circuit.

   Remember also that when a voltmeter is connected across (in parallel) with a portion of a circuit it changes the potential difference by its own effect on the circuit and since it also is connected in parallel with a part of the circuit it reduces the effective resistance of that portion which increases in some degree the total current flowing in the complete circuit.

   Therefore voltmeters are designed to have the highest resistance possible so as not to change materially any circuit to which they may be applied.

5. It is considered good instrument practice in multirange instruments to have the range switch on the highest possible range and then the user can progressively switch down to the range that produces an acceptable reading. A good acceptable reading would be one in which the pointer is indicating in the upper fifth of the scale. (Nearly maximum deflection.) Apply power and observe pointer deflection. When the instrument pointer has come to rest, the current is indicated by the position of the pointer on the scale.

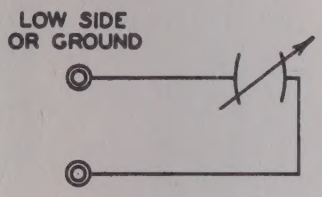
6. After the desired measurements have completed, turn off the current supply and disconnect the instrument terminals from the source of current. If the instrument leads are left connected and circuit changes made damage could result to the instrument being on a range setting lower than the newly applied power value.

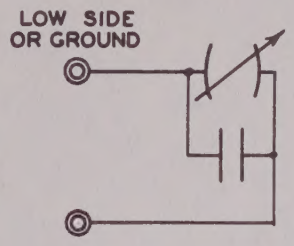
SENSITIVE RESEARCH INSTRUMENTS have a data card attached to it or mounted in its case. This data card detailing the accuracy and electrical characteristics together with the instrument panel engraving will readily enable the user to operate our instruments to their full accuracy and their personal satisfaction.

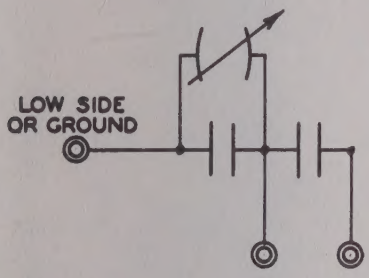
SPECIFICATIONS & SCHEMATIC DIAGRAMS
OF
ELECTROSTATIC VOLTMETERS

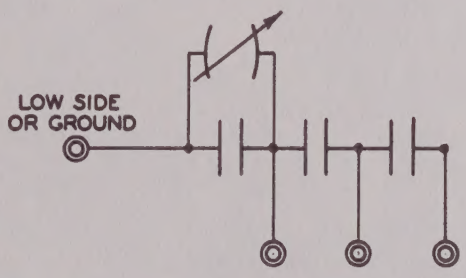
TYPE Double Pivoted MOVING VANE
MODEL ESO INSTRUMENT Nº
CODEWORD
RANGES
DIAGRAM Nº

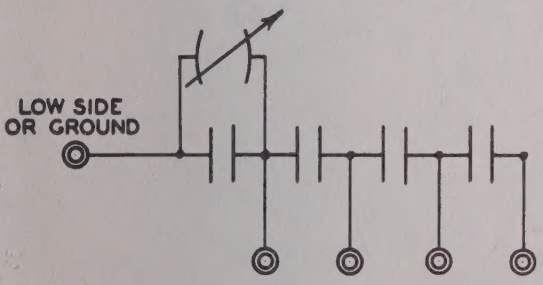
SPECIAL FEATURES











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